PRINCETON UNIVERSITY

Department of Civil and Environmental Engineering

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February 17, 2003

Dr. David Starr
AQUA Validation Scientist
NASA Goddard Space Flight Center, Code 912
Greenbelt, MD 20771

By email: David.O.Starr@nasa.gov

Dear Dave:

Attached is my AMSR-E validation project progress report for the current year for grant NAG5-11111 “Land Surface Modeling Studies in Support of AQUA AMSR-E Validation”. The year 3 budget is also attached.

If you require further information about our activities, please feel free to contact me.

Sincerely yours

Eric F. Wood
Professor

cc: Jim Closs <Jim_Closs@sesda.com>
file: 155-6020
ORPA (M. Thompson-Siegel)

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Year 2 Progress Report and Year 3 Budget

Submitted to

National Aeronautics and Space Administration
Validation Studies for Data Products from the Earth Observing System AQUA (PM) Platform and EOS-related Spectroscopic Studies
NASA/GSFC
(David Star, EOS Validation Scientist)

Land Surface Modeling Studies in Support of AQUA AMSR-E Validation

Renewal Date: August 31, 2003

Principal Investigator:
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1. INTRODUCTION

The AMSR-E validation plan includes an evaluation of the derived level-2 and level-3 soil moisture product to assure that AMSR-E provides products that are both accurate and appropriate for hydrological modeling. A combination of process-based hydrological modeling, airborne remote sensing, and the simulation of the AMSR-E measurements, including the AMSR-E antenna pattern, orbital characteristics, and the gridded products is being carried out to provide support to the AMSR-E validation. The investigation focuses on understanding the heterogeneity at various spatial scales for validation and the validation of AMSR-E soil moisture products with data at different depths from in-situ measurements and hydrological modeling.

The project is structured around four tasks, as follows:

Task 1: Test and Extend the Land Surface Microwave Emission Model (LSMEM)
The LSMEM simulates the microwave emission from the land surface, and includes the effect of soil moisture, vegetation and temperature on the surface emission, which is measured at the TOA by AMSR. The LSMEM will be further tested using data from recent and planned field experiments in the Southern Great Plains. These field data will help us to compare model predictions with airborne measurements of microwave brightness over a range of frequencies.

Task 2: Produce Real-time AMSR-E Simulated Science Data Products.
Through running LSMEM with the surface conditions estimated from our North American Land Surface Data Assimilation System (NLDAS) project at 10 km, which produces the land surface hydrology over the contiguous U.S., hourly AMSR-E brightness temperatures at real time are being simulated. Also, a retrieval of AMSR-E 25 km soil moisture will be estimated with LSMEM and supplementary data sets from NLDAS. Using LDAS validation point soil moisture data, we will evaluate the quality of the NLDAS (VIC-3L) surface hydrology simulations.

Task 3: Produce Retrospective SMMR Simulated Microwave Brightness Temperatures
In a retrospective mode, we plan to utilize the simulations from NLDAS with our LSMEM to simulate the SMMR 6.9 GHz brightness temperatures. These simulations will help the AMSR-E science team better understand the spatial and temporal variability of these brightness temperatures, and therefore help to better interpret the AMSR-E data. This becomes more significant due to the high RFI at AMSR-E C-band observations.

Task 4: Evaluate AMSR-E Validation Plans
Through comparing soil moisture data from in-situ measurements, air borne remote sensing, and hydrological modeling, this task will provide critical insight into the validation sampling plans. This will involve understanding the sub-grid heterogeneity and how to use hydrological modeling to upscale the in-situ point data to a product comparable with AMSR-E 25km soil moisture product, as well as the possible problem due to the different depths represented by different data sources.

2. ACTIVITIES DURING THE LAST YEAR

During this year, research at Princeton focused in three areas: (i) using LSMEM to estimate soil moisture from the airborne ESTAR observations during SGP99 (task 1); (ii) using LDAS real time data as LSMEM inputs to simulate AMSR-E brightness temperature at C-band and X-band (task 2); and (iii) participating in the Soil Moisture Experiment '02 (SMEX02) AMSR-E field validation campaign in Iowa (tasks 1 and 4).

2.1 Using LSMEM to estimate soil moisture from ESTAR observations during SGP99

The SGP99 provides comprehensive data sets for evaluating microwave remote sensing of soil moisture algorithms that involve complex physical properties of soils and vegetation. LSMEM is used to retrieve soil moisture from brightness temperatures collected by the airborne ESTAR L-band radiometer.

Figure 1 shows the flow chart of LSMEM soil moisture retrieval algorithm. Besides the horizontal polarized brightness temperature from ESTAR, the LSMEM inputs for each pixel to retrieve soil moisture include effective soil temperature, vegetation temperature, soil texture, surface roughness, soil bulk density, vegetation water content, and a vegetation structure parameter. All data were processed into grids of 0.005 degree resolution for the region encompassed by 34°N to 38°N in latitude and -97°W to -98.5W° in longitude.

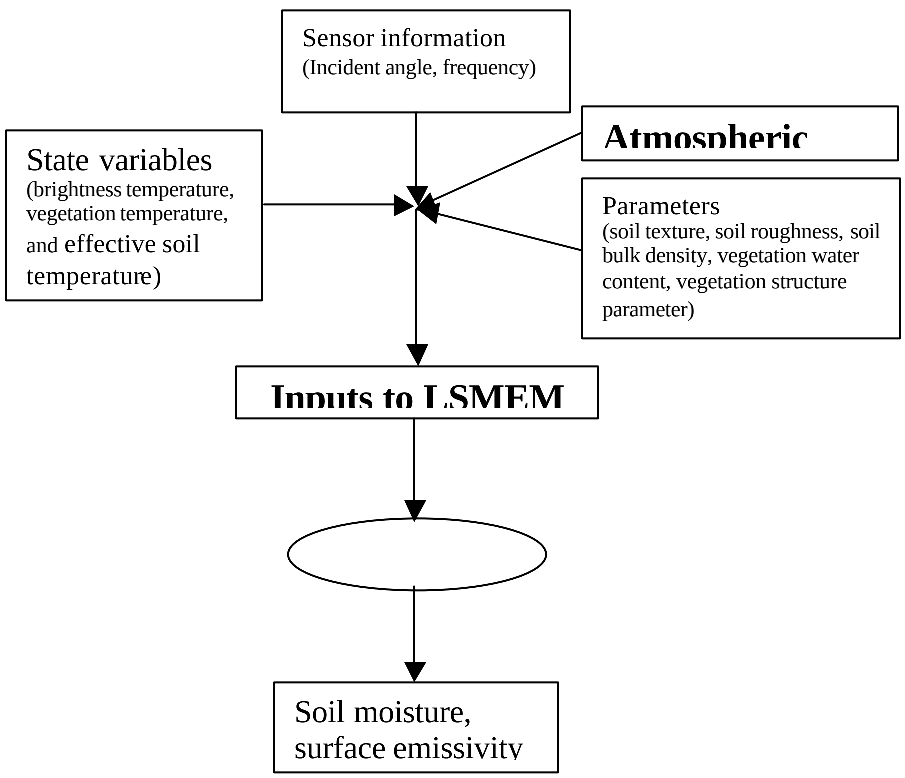
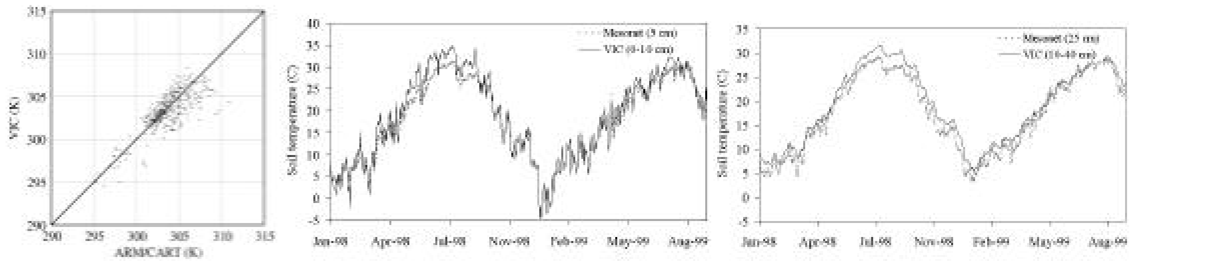


Figure 1 Flow chart of LSMEM soil moisture retrieval algorithm.

The surface and deep soil temperatures were obtained from Variable Infiltration Capacity (VIC) land surface model (Liang et al., 1994; Chekauer et al, 2002), running as part of the North American Land Data Assimilation System (NLDAS) (Mitchell et al., 2000; Mitchell et al., 2002). As part of the NLDAS validation activities, VIC modeled states were compared to observations. Figure 2a shows VIC surfa ce temperature validation when compared to all ARM/CART solar and nfrared observing systems (SIROS) sites for July, 1999; Figure 2b and Figure 2c show the time series of soil temperatures from VIC and Oklahoma Mesonet observations at Apache (34.91° N, 98.29°W). Based on the VIC NLDAS validation, it appears that the VIC-derived surface temperature and soil temperatures are accurate and suitable for LSMEM soil moisture retrievals.



(a) (b) (c)

Figure 2 (a) VIC surface temperature validation compared to all ARM/CART solar and infrared observing systems (SIROS) sites for July, 1999; (b) and (c) the time series of soil temperatures at different layers from VIC and Oklahoma Mesonet observations at Apache (34.91° N, 98.29°W)

Figure 3 shows the LSMEM retrieved soil moisture from ESTAR images during SGP99. On July 8th and July 9th, the area was mainly dry except in the northern part, which experienced a total precipitation of 40 mm to 80 mm from June 29th to July 1st. Images for July 14th, 15th, 19th, and 20th illustrate the dry down process. At the end of the SGP99 experiment, the soil moisture across the study area was below 10%. From July 14th to July 20th, soil moisture decreased more than 30% (volumetric soil moisture) in the northern part of the SGP99 domain, decreased about 20% in the middle, and less than 10% in the southern part.

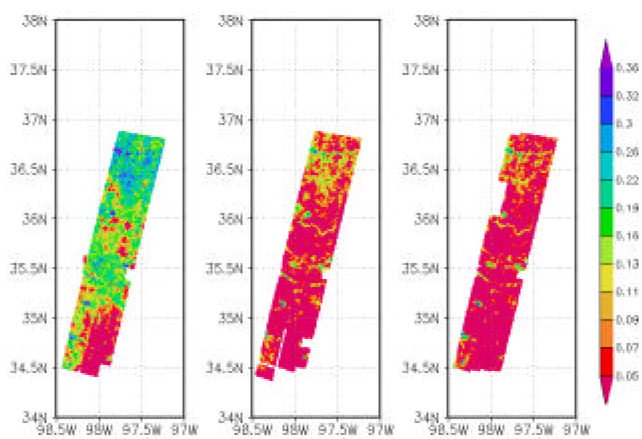


Figure 3 LSMEM retrieved soil moisture from ESTAR images during SGP99.

Figure 4 shows the validation of the averaged soil moisture for the sites in each region. The root mean square errors are: CF=2.8%, ER=2.3%, LW=1.8%, and 2.1% for all sites. Compared to other microwave soil moisture retrieval algorithms, the LSMEM performs very well (Jackson et al, 1999). This encourages further application of this physical model in retrieving soil moisture from space-borne platforms such as AMSR-E.

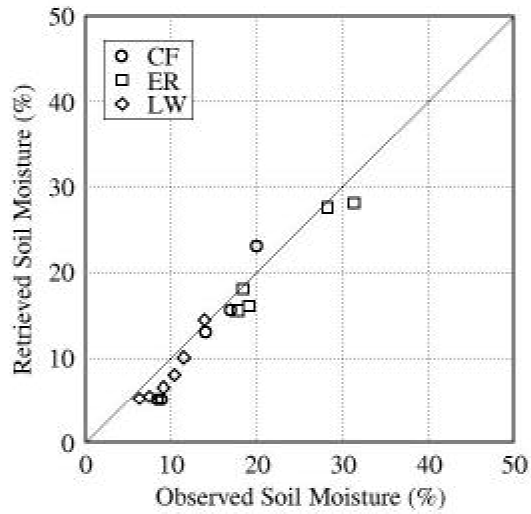


Figure 4 Validation of the averaged soil moisture for the CF, ER, and LW.

Through the site by site validation, we notice that LW12 had the largest inconsistency detected: for July 8th and July 9th the retrieved soil moistures were 8.5% and 5.6% lower than observations respectively. Analysis of the field sampled raw data shows that a part of these errors could be due to high heterogeneity of this site. The standard deviations of observed soil moisture for LW12 on July 8th and July 9th is the highest among all the LW sampling sites: 9.95% and 8.77%. Figure 5 shows the raw data for each of the sample ID for this site during ESTAR data collecting days. Using July 8th as an example, the highest sample value for this site was 36.9% and the lowest value was 5.0%, sample ID-1 and sample ID-2 were only 100 meters apart while the values were 6.6% and 31.9%. Values for sample ID-2 on other days differed significantly from those on the first couple of days, this suggests even higher heterogeneity around that location. The average value used for validation of this site was 19.5%, much larger than that for the adjacent LW13 (8.2%). As a result, remote sensing soil moisture data will be less accurate in pixels with complex topography.

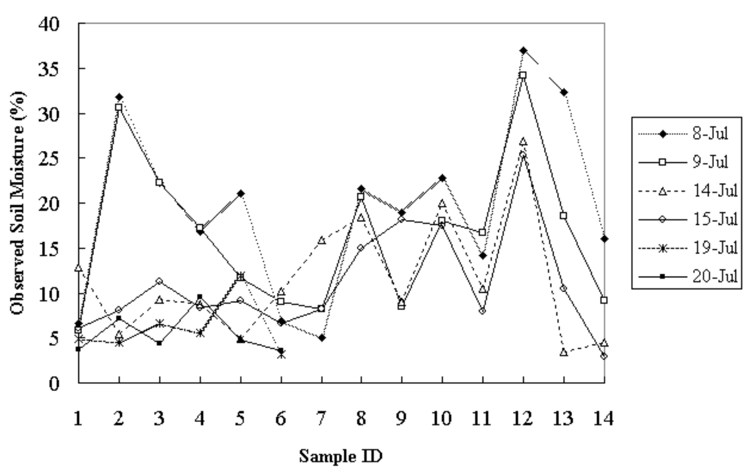


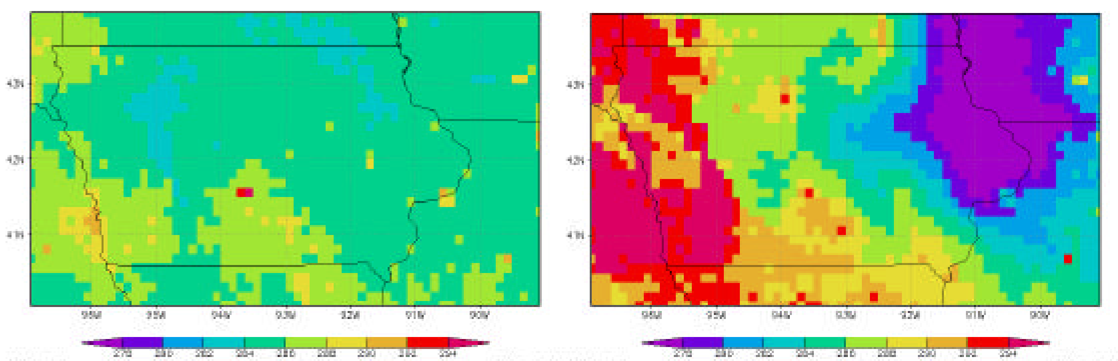
Figure 5 Raw data for each of the sample location for LW12 during ESTAR data collecting days.

Based on this part of the research, we can conclude that:

- Compared to other microwave soil moisture retrieval algorithms, the LSMEM performs very well, which encourages further application of this physical model in retrieving soil moisture from space-borne platforms such as AMSR-E.
- Using intensive field measurements from Oklahoma Mesonet, validation results at CF, ER, and LW sites, have RMS errors in volumetric soil moisture of 3.1%, 2.6%, and 2.0% respectively. Thus hydrological modeling has shown great potential for AMSR-E validation.
- Spatial heterogeneity is the main problem we need to solve for AMSR-E validation.

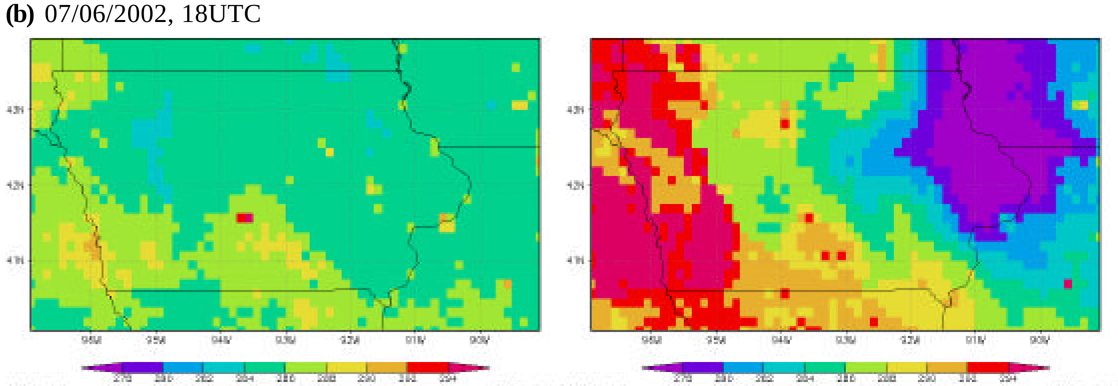
2.2 Using NLDAS real time data as LSMEM inputs to simulate AMSR-E brightness temperature at C-band and X-band

Using NLDAS real time data (soil moisture and soil temperatures) as LSMEM inputs, we simulated the AMSR-E real time brightness temperatures at C-band and L-band during SMEX02, carried out near Ames Iowa. Due to a sparseness of data and parameter sources, constant values are used for the vegetation structure parameter and soil roughness. Figures 6 and 7 show how the brightness temperature changes from a very dry condition (July 1, 2002) to a wet condition (July 6, 2002), and the resulting expected difference between the brightness temperatures at C-band and X-band. The latter aspect is important as C-band observations have shown significant RFI and therefore X-band data sets are expected to be the measurement basis for AMSR-E soil moisture product, which needs to be validated.



(a) (b)

Figure 6 LSMEM simulated AMSR-E 6.9 GHz brightness temperature during SMEX 02 **(a)** 07/01/2002, 18UTC **(b)** 07/06/2002, 18UTC



(a) (b)

Figure 7 LSMEM simulated AMSR-E 10.7 GHz brightness temp erature during SMEX 02 **(a)** 07/01/2002, 18UTC **(b)** 07/06/2002, 18UTC

Conclusions for this part of the research are:

- AMSR-E real time simulation algorithms are ready, a sound parameterization based on SMEX02 are expected.
- X-band brightness temperature has similar sensitivity to soil moisture changes as the C-band brightness temperature.

2.3 Participation of SMEX02 in Ames, Iowa

Three of our students and stuff took part in the SMEX02 to collect data for AMSR-E validation for three weeks. Our contribution involves watershed sampling, regional sampling, vegetation sampling, soil property sampling, etc. We will use this experience and data to improve our LSMEM for the SMEX02 region.

3. YEAR 3 PLANNED ACTIVITIES

The following activities will be the focus of the next year.

1. Participation in the SMEX03 validation fieldwork, being planned for July 2-18, 2003 in the southern Great Plains region (see http://hydrolab.arsusda.gov/smex03/ for more details.)
2. Produce real-time AMSR-E simulated brightness temperatures with parameters collected from SMEX02. This task will carry out the simulations at high spatial resolution and scale to the AMSR-E resolution to understand the scaling between the filed-scale validation data and the AMSR-E resolution.
3. Further test LSMEM algorithm by using TRMM/TMI 10.7 GHz brightness temperature to retrieve soil moisture during SGP99, which will provide insight to the studies for the upcoming SMEX03 validation experiment.
4. Compare brightness temperatures and soil moisture (observed or retrieved) from different data sources (airborne remote sensing at L band and C band, land surface modeling, and satellite remote sensing), with the aim to set up a strategy validating AMSR-E with multi-scale validation data, each with its own resolution and error characteristics.

4. PUBLICATIONS FROM THE PROJECT

Huilin Gao, Eric F. Wood, Matthias Drusch, Wade Crow, Thomas J. Jackson. 2003. Using a Microwave Emission Model to Estimate Soil Moisture from ESTAR Observations During SGP99, *Journal of Hydrometeorology*, submitted.

YEAR 3 BUDGET

Project: Land Surface Modeling Studies in Support of AQUA AMSR-E Validation
Investigator: Eric F. Wood

Year 3
From: Sept. 1, 2003 to Aug. 31, 2004

	COSTS	NASA USE ONLY	
	A	B	C
1. Direct Labor			
1.1 PI (summer)	13,945		
1.2 Research Associates	17,258		
1.3 Graduate Student (academic year)	8,450		
1.4 Graduate Student (summer)	3,250		
1.5 Indirect benefits on 1.1 & 1.2	10,578		
Subtotal (salaries, wages and benefits)	53,480		
2. Other Direct Costs:			
2.1 Graduate Student Tuition	6,950		
2.2 Travel	2,500		
2.3 Computer Equipment	0		
2.4 Computer Services	1,400		
2.5 Supplies	200		
2.6 Publication	1,000		
2.7 Sub-contracts			
2.8 Consultants			
3. Indirect Costs	33,977		
4. Other Applicable Costs			
5. SUBTOTAL -- Estimated Costs	99,507		
6. Less Proposed Cost Sharing (if any)			
7. Carryover Funds (if any)			
8. Total Estimated Costs	99,507		xxxxxxxxxxx
9. APPROVED BUDGET	xxxxxxxxxxx	xxxxxxxxxxx	